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Participatory modelling of the trajectories of agro-sylvo-pastoral systems at landscape and community levels in West Africa – the case of Senegalese groundnut basin

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1 Introduction

West African populations are rapidly increasing and are becoming more urban (Ouedraogo, 2007). Due to improvement of living standards, consumption habits in this region are also evolving. The fast growing demand for livestock products creates an important gap between the supply and demand (Kamuanga *et al.*, 2008). Competition over resources increases due to rural population growth and the resulting cropland expansion (van Asselen & Verburg, 2013). Furthermore, the climate stays highly unpredictable with very high inter-annual variability. To predict the future of agrosystems in this context, it is important to identify the ecological and social drivers of their trajectories. The objective of this research is to explore the trajectories of agro-sylvo-pastoral systems at landscape and community levels through participatory modelling. The study area is located nearby Niakhar, in the Senegalese basin, which is an area that has been well-documented since 1960 (Lericollais, 1999; Audouin, 2014). The observed environmental changes are representative of the West African trends described above. Three villages in the area have been chosen for the analysis. These villages are exposed to similar constraints and pedo-climatic conditions but have different landscape structures and diverse combinations of household types. The hypothesis is that despite the contrasts and diversity of household's strategies certain ecological properties are conserved at the landscape level. These properties (plant and animal biodiversity, crop-livestock integration and spatial heterogeneity) are thought to increase the resilience of the whole socio-agro-ecosystem to climatic, pest and market hazards.

2 A role-playing game to define past and future village trajectories with farmers

Three different decision levels are classically distinguished in agronomy: the strategic, tactical and operational decision levels (Sebillote & Solers, 1988). Strategic decisions are define as those that guide the production system for numerous years by choosing production activities and productive resource allocation (human migrations, crop expansion, change in crop or livestock activities, etc.). Tactical decisions aim at managing the production system over seasons. Operational decisions use the resources allocated on a daily basis. Tactical and operational decisions can be observed on the basis of farm survey or on-farm immersions (Vayssières *et al.*, 2007). Strategic decisions are more difficult to apprehend due to their long term dimension and the fact that they depend on household and community levels. We consequently plan to use a role-playing game to capture farmer's strategic decisions and the resulting past and future village trajectories. The role-playing game combines a game-board and a simulation model, responding to each-other (Le Bars *et al.*, 2011; Matthews, 2006). Both represent a hypothetical village (Fig. 1). Farmers take strategic decisions during the game. Each playing round is a year. Farmers' strategic decisions are inputs for the computerized model which simulates the consequences of these strategic decisions on the performances of the different farm types and at the village level. Computerized model outputs are information provided to farmers at the end of each playing round. This information is used by farmers to adjust (or not) their strategies during the next playing round.

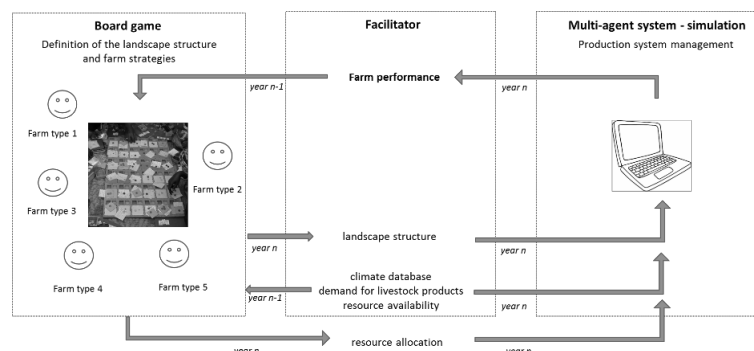


Fig. 1. Interactions between farmers and MAS during the role-playing game (arrows are information flows)

This sequence of role-playing and simulation is implemented for 10 to 50 rounds, i.e. 10 to 50 years. Played scenarios are based on real demographic, climatic and market series (from 1960 to 2015) or projections (2015 to 2050). Both strategic decisions taken by farmers while playing the game and resulting simulation are recorded, and used to describe and analyse village trajectories.

3 A multi-agent system to assess the resilience of socio-agro-ecosystems along their trajectories

The computerized model used for simulations in the role-playing game is a multi-agent-system (MAS). It represents the functioning of the socio-agro-ecosystem at landscape and community levels. Model inputs are of two types: i) parameters directly impacted by farmers' type and strategies (the landscape structure, the action plan and corresponding decision rules) and ii) environmental parameters (resource availability, unreliable weather and variations of demand for livestock products). The MAS integrates two systems in interaction: a decision system and a biophysical system (Fig. 2). The decision system represents farmers' tactical decisions, i.e. their action plan (one per farmer type) and its implementation. It defines the technical actions performed by farmers on plots and cattle over seasons. The biophysical system is essentially a stock-flow model. It represents the biomass productions and the organization of biomass flows through livestock, soil, rangelands, crops, and feed, forage and manure storage structures. The majority of these flows are defined by the technical actions decided by the decision system (e.g. crop manuring). Biomass flows are translated into nutrient, working-time and money flows to calculate different sustainability indicators at farm and landscape levels.

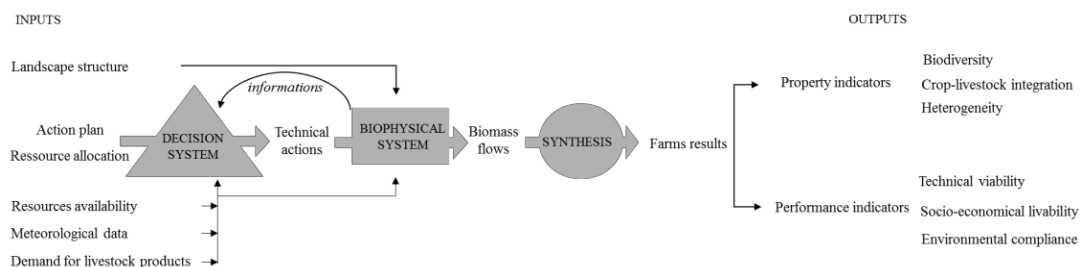


Fig. 2. Conceptual model of the MAS (adapted from Vayssières *et al.*, 2007)

Two types of output indicators are provided by the model: property and performance indicators. Property indicators are used by researchers to verify if some properties (biodiversity, integration and heterogeneity) are conserved over time to increase the resilience of the performances of the whole socio-agro-ecosystem. Three types of performances will be analyzed at landscape level: technical viability (crop and livestock production, workload), socio-economic livability (food self-sufficiency, gross margin) and environmental compliance (nitrogen balance, nitrogen use efficiency). Some of these performance indicators (productions, workload, food self-sufficiency and gross margin) are also the indicators that are provided to farmers at farm level during role-playing games.

4 Conclusions

In West Africa, the demographic, economic and environmental context is changing at a rapid pace, reorganizing rural territories. By using a participatory simulation, farmers are involved in exploring collectively past and future trajectories of agro-sylvo-pastoral systems at landscape and community levels. The proposed game links a board game and a multi-agent system. The role-playing game puts farmers in a position to choose activities and allocate resources on a yearly basis. The board is used to materialize these choices and the MAS provides information on their consequences on the year performances of farms and the whole territory. After N iterations, i.e. an N-years exploration, the dynamic of choices and their consequences can be recorded and considered as probable past or future trajectories.

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